PTO/PCT Rec'd 28 FEB 2000
09/423916

Surgical Microscope

MICROSCOPE STAND, ESPECIALLY FOR A SURGICAL MICROSCOPE

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BACKGROUND OF THE INVENTION

Surgical microscopes are finding increasing use in surgery. Because of their weight, they must be mounted on stands. Many well-known manufacturers have marketed stands which meet the requirements for holding the load of the surgical microscope well with respect to mechanics and statics. For instance, the applicant markets stands with the designation OH, which are produced by Mitaka, among others. Examples of such stands appear in EP 0 628 290 A1 and EP 0 476 552 A1. Most modern stands have parallelogram arms so that they can bear the load of the surgical microscope over the greatest possible distances without bending or twisting, so that the mobility and radius of action of the microscope are as great as possible. One such design is presented in EP 0 628 290 A1.

The Contraves company has also marketed a similar stand with two separate balance weights, one of which can be moved horizontally on a horizontal parallel control arm, while the other can be moved vertically on it. Such a stand is also described in EP 0 476 551 A1.

One of the concepts of the manufacturers of the usual surgical stands is that more massive parts and greater weights (balance weights) are good for stability of the stand while it is being used. For instance, the stands sold with the "OH" designation were made of relatively massive cast aluminum tubes, with some stepwise transitions to different cross-sections for integral vibration damping.

As noted above, the OH stands are described by EP 0 628 290 A1 and were marketed by the applicant of that EP 0 628 290 A1 jointly with the applicant of this invention.

To gain improvements for users, though, a proprietary development with the goal of improved stand characteristics was carried out. The result of that development is described in WO 97/13997 A1 and WO 97/20166 A1.

In the current invention, the applicant proceeds from the novel concept that even light microscopes can have good stability if they are designed with improved components. Significant advantages over the known massive stands would be better mobility and more universal usability (fewer problems with the carrying capacity of the floor, etc.). On the other hand, it should be possible to provide users greater radii of action around the stand with the same microscope weight.

It was recognized in the invention that the weight reduction alone is not sufficient if the quality of the damping characteristics of the important components is not adequately considered.

The supports used according to the invention, which can, if necessary, also be used to construct parallelogram carrying arms, should as much as possible be simple, straight parts with high strength.

In meeting these requirements, the applicant created a stand using at least one support of a fiber-reinforced plastic. This stand is described in WO 97/20166 A1, cited above.

On the basis of the concept of replacing the usual steel or aluminum parallel arms by fiber-reinforced plastic parts, especially tubes, according to the invention, weight can be saved while the strength or the radii of action can at the same time be increased. Therefore the stand is lighter. This effect is detectably increased by the fact that the weight of the mount itself, as well as the weight of the load which must be compensated by balance weights, are reduced.

Introduction of fiber-reinforced plastic tubes into microscope stand design is indeed revolutionary and supports the solution of the objectives cited initially; but this new principle does not yet explicitly consider the vibrational behavior which a stand can exhibit.

The path of weight reduction using fiber composites and plastic was also followed in another area of stand design, X-ray technology, as presented in DE 42 14 858 C1. There, a C-arc of plastic foam was provided as a load-carrying part. It determines the shape, and is surrounded by a fiber-reinforced plastic which takes over the load-bearing properties. If this known design should exhibit a considerably lower weight, then, according to the prior art teaching, it would be necessary to produce a profile in closed form of only fiber-reinforced plastic.

SUMMARY OF THE INVENTION

This invention, in contrast, recognizes that the objective is not reached optimally by this known teaching. Although modern plastic-fiber composites attain good stability with good vibration properties and low weight, it is not enough to achieve just "good" values, especially in surgical microscopy, if one considers the often vital importance of the optimal vision for an operator.

The smallest changes in the microscope position unavoidably excite vibrations in the entire structure. Therefore it is the objective of this invention not only to further optimize parts, but to find solutions which will have positive effects on the vibrational behavior of the stand; that is, to prevent vibration or to damp all kinds of vibrations optimally. Low-frequency vibrations, such as those in the range of 0 - 5 Hz, are to be attacked.

A person skilled in the art knows that such problems are hard to solve and that application of mathematical-physical aids and theories often does not provide the desired

result. On the other hand, even small improvements are worth trying for, as they improve the comfort of the user and accordingly increase the safety of the operation.

This objective is achieved according to the invention by two measures which can be used alternatively or together.

A) One measure is to damp the vibration of high-strength stand tubes made of fiber composites by combining them, along their length, with another supporting material having a substantially different, usually lower, modulus of elasticity.

According to the invention, then, one should not use just a single supporting material, such as in DE 42 14 858 C1 cited above, and a material that gives the shape, but instead, two supporting materials with entirely different vibrational behaviors. Figure 3 of DE 42 14 858 C1, just cited, does show a combination of an aluminum extrusion and a fiber-reinforced plastic, but for another purpose, in a different stand, and in a way which does not approach the objective of the invention, optimizing the weight/vibrational damping relations.

The prior art teaching of this DE 42 14 858 C1 provides, as a non-weight-optimized solution, embedding the aluminum extrusion mentioned in the fiber-reinforced plastic in place of wires used to support rollers. The aluminum extrusion used according to the applicable prior art teaching has practically no vertical section modulus. It is not even required, as it is provided by the tubular plastic tube with fiber reinforcement. The reason for using the extrusion is not optimization of the weight/vibration behavior, but improved mounting of peripheral wires for the roller support mentioned.

In contrast, the combination according to the invention provides a combination of tubular parts, such as a segment of aluminum tube, which is cemented to an inner or

outer fiber composite tube. It could even be, as is preferred, an aluminum tube to which the fiber composite tube is cemented so that it becomes a composite structure (metal/plastic or plastic/metal, or comparable sandwich structures repeating the two materials). Aluminum is preferred for its weight and for its lower modulus of elasticity (E-modulus); but the invention is not limited to that material. One skilled in the art knows other materials which he could use to replace aluminum, such as soft-alloyed steels, or a plastic having a different E-modulus than the fiber composite material (it could even be fiber-reinforced itself).

Only the requirement of the invention for optimized damping and the recognition that both supporting materials must provide a vertical section modulus lead to actual optimization of the carrier with respect to weight minimization and simultaneous damping optimization.

Embodiments could use thermoplastics, duroplastics, thermosetting plastics (epoxy resins) or mixtures of them as plastics for both the high-modulus and low-modulus materials. Preferred fiber materials are carbon fibers, aramide fibers, glass or mineral fibers, polyamide fibers, natural fibers or cloths, or a mixture of those.

With respect to the connection between the high-modulus and low-modulus materials, it should be noted that this is not limited to a rigid connection, such as a glued joint. It could also be a loose plug and socket connection so that the two tubes can be axially shifted with respect to each other within certain limits.

That can also be accomplished with an elastic cement. If desired, another damping, e. g., frictional, intermediate layer could also be provided instead of an adhesive.

On the other hand, the invention is not limited in this respect to use of fiber composite materials. Instead, it also covers composite structures of different metals, such as steel and aluminum.

B) The other measure is to place damping materials between the high-strength parts and/or between the stand and its base or mounting surface at least one place, as stated in WO 97/20166 A1 mentioned above. In this case, care should be taken to have as little bad effect as possible on the accessibility of all the joints or bearings between parts of the stands. Although it would also have a damping effect, it would undesirably reduce the operating comfort.

The two measures, A) and B), can be applied independently of each other; but a combination of them has proved to be particularly advantageous. Their common inventive aspect is the combination of strength with damping properties, which apparently counteract the strength.

The weight of the stand or its arms can be further reduced according to a further development of the invention, in which the tubular arms are prestressed. Such prestressing acts differently on the different strengths and elasticities, according to the invention, of the two arm materials, so that it does not have a bad effect on the damping optimization according to the invention.

The idea of prestressing according to the invention is, however, not limited to metal-plastic composite tubes. It would also be new and inventive for one-piece stand arms even if only for weight reduction, in comparison with the known arms.

The invention is not concerned with the arms or tubular parts alone, though; but also with the base of the stand which, on one hand, carried the total weight of the stand and the

load on it, with respect to potential inclusion of damping elements such as feet, and, on the other hand, represents a significant weight factor.

According to the state of the art, the stand base provides stability to the stand in certain designs due to its intentionally high weight. Tigliev, for instance, in his US Patent 5,609,316 A, required that the stand base have "sufficient weight" to "attain the desired stability" (see column 2, lines 48-50). Other modern designs, such as that disclosed in WO 97/13997 A1, though, balance the structure so well that it does not need a heavy foot.

As a further objective, this invention intends to reduce the weight of the foot with a high-strength design.

This objective is attained by a novel composite structure of the foot. That is, obviously, also independent of the damping features mentioned above, and is new and inventive for stands.

The design is made up essentially of an upper and a lower plate sandwiching a honeycomb structure, or cemented to it.

According to one further development of this invention, the upper and lower plates are joined at at least one point and solidly connected, by bolts, for instance, so as to avoid shearing movements between the two plates as much as possible. At the same time, the particularly good firmness of the honeycomb structure between the plates gives a particularly stable, but still light, structure.

The junctions are preferably designed simultaneously as mounting points for wheels or feet, which are preferably adjustable upward or downward.

To make the stand movable, while also being able to have it stand solidly when needed, with damping, the invention provides for an odd number of wheels which can be lowered (preferably 5 of them), which are preferably supported from the ground on a damping material.

The odd number is advantageous with respect to tipping. As a variation, a more or less closed damping ring could also be provided which, like the feet, can be lowered to the floor as an alternate to transport wheels.

In a further embodiment of the invention, there is a new lowering means for the wheels and/or feet of the stand. It is produced by a common chain drive working with toothed gears, each of which is connected to a screw with a coarse pitch so that all the feet or rollers can be lowered or raised simultaneously with a single operation.

Thus the invention offers particularly suitable and adapted mechanical parts with low weight or high strength and improved vibrational behavior as the parts that are required geometrically. Other special developments and variations are described and protected in the patent claims.

The connection between the fiber-reinforced tubes or arms and the other parts can be through a metallic interface which can be mounted to a particular tube or arm by screws or pins or by cementing.

For the particular embodiment of the invention mentioned under A) with statically and dynamically optimized arms due to making the arms of the stand as composite materials with high-strength (e. g., fiber-reinforced) tubes with a high modulus of elasticity (e. g., 100-210,000, especially 150-200,000), the high-strength tubes are connected with metal tubes, which in the preferred embodiment are, if desired, aluminum alloy tubes or tubes with

comparable, not high, E-modulus (ca. 50-80,000). A special advantage of this design is found, in the case of fiber reinforcement, to be the possibility of assembling the fibers, such as carbon fibers, in the null position; that is, parallel to the tube axis. Then the metal tube holds the fibers in position on the synthetic resin to some extent. The null-layer fibers improve the bending strength and stiffness; on the other hand, the modulus of elasticity in the torsional direction is reduced.

In the case of tubes cemented together — especially with fibers in the null position — this also provides stiffening of the metal tubes themselves, so that the strength is not just the sum of the strength of the metal tube and the strength of the fiber-reinforced plastic. The torsion which occurs in any case is taken up optimally by the metal tube, especially an aluminum tube.

Another measure which can also be used independently of those mentioned above is established according to the invention to attain added vibrational damping in all cases and so to achieve still better operating reliability:

In this particular embodiment of the invention, as already stated in ~~WO 97/2016 A1~~ WO 97/20166, at least one interface between two load-carrying parts of the stand is kept free of stress. In the simplest case, that can be done by loosening the connection between these parts (such as a screw connection) so that while the parts cannot be separated from each other, vibrations or oscillations, especially in the low-frequency range, are not transmitted well.

Additional damping effects are attainable if, as stated under B), damping materials are provided as intermediate layers at the corresponding interfaces.

As a significant effect of the invention, these measures prevent vibrations occurring at the microscope, initiated by small shocks or changes of position, from passing through the

entire stand and perhaps being reflected at the mounting surface (floor or ceiling) back through the stand to their origin.

Preferred locations for the stress-free separation are those places in the stand at which there is a balanced equilibrium so that hardly any bending stresses appear. In one example embodiment the position immediately below the main bearing in the stand was considered as such a place, because the stand is balanced above the main bearing, especially if it is designed according to WO 97/13997 A1.

Other areas for stress release and/or insertion of damping materials are, if desired, those between the bearing mounts for wheels, mounting feet, the stand base, and the other parts of the stand.

For example, the central vertical support can be set on a pivot connected to the foot, possibly so that it can rotate with an elastic damping coating.

Also, the vertical support tube itself can be interrupted, with the break bridged over by an elastic damping intermediate element.

When damping elements are used in the vicinity of the mounting feet, added damping is attained by using a basic balance design according to WO 97/13997 A1 and suitable choice of material.

Swinging of the part of the stand vibrating in a horizontal plane and swinging of the part of the stand vibrating in the vertical plane can lead to a vibrating tipping moment in the vertical stand and then to the base or, in a parallel plane, to the floor, which is damped by the damping feet. On the other hand, it can lead to a translational moment at the foot, parallel to

the floor. This moment is also damped, by frictional damping, by the mounting feet of damping material which are preferably used.

A rubber or polyurethane or polyether urethane or similar material is preferred as a damping material according to the invention, especially a closed-cell or mixed-cell foam.

The properties of the preferred materials lie in about the following parameters:

Static modulus of elasticity	0.2 - 3 N/mm^2
Dynamic modulus of elasticity	0.5 - 4 N/mm^2
Mechanical loss factor	0.1 - 0.2
Inherent frequency of the material	> 5 Hz

each measured as specified in DIN 53513.

As examples of preferred materials, Sylomer ® M12, Sylomer ® M25 P14 or Sylomer ® P12, Sylomer ®P25 P15 is selected for the dynamic load range of 0 -0.3 N/mm^2.

Damping materials can be combined if necessary. The invention also covers variations with certain shapes for the damping materials. For instance, cutouts, such as blind holes or the like, can be provided for further influence on the damping.

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BRIEF DESCRIPTION OF THE DRAWINGS

The invention is explained in more detail using example embodiments, with the schematic drawing. The figures are described together. The figure description and the list of reference symbols make up a unit mutually supplemented by the other parts of the description and claims in the sense of complete disclosure. Identical parts have identical reference symbols. Identical reference symbols with different indices indicate similar parts with the same function. The figures are only for examples, and are not necessarily drawn in correct

proportion. The reference symbol list is compatible with those of WO 97/13997 A1 and WO97/20166 A1. The figures show:

Figure 1: an oblique view of a stand according to the invention with fiber-reinforced arms according to the invention and the same kind of stand;

Figure 2: a symbolic representation of a new kind of stand with a zone of stress-free separation;

Figure 3: a symbolic representation of a stand support tube according to the invention with fiber orientation outside the null position;

Figure 4: a symbolic representation of a composite stand tube according to the invention;

Figure 5: a section of a stand base according to the invention with rollers and feet which can be lowered;

Figure 6: another section of this base with the feet lowered;

Figure 7: another section of this base in a plan view;

Figure 8: a section through a variant of the stand base according to the invention;

Figure 9: the moments map (arrows, which indicate the vibration) for a symbolic example embodiment;

Figure 10: a section through a prestressed arm; and

Figure 11 a variant of the above.

a DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A stand base 23 carries a pillar 1 which holds the main bearing 18. In the variant shown in Figure 1, the pillar 1d is mounted in a pivot bearing 34 so that it can be rotated with respect to the base. According to Figure 2, the pillar 1 is in 2 parts with an interface 96a which, in this example, is designed like a flange, dividing the pillar into two segments, 1a and 1b. There could also be a support block for the bearing 18 mounted on the pillar 1a, so that an interface is formed between it and the pillar 1a. In one variant, no significant stress operates in the vertical direction at interface 96a or in the direction of the stand extension, so that vibrational forces are transmitted poorly there. The screws indicated symbolically are not prestressed, for example. This has a secondary role with respect to production technology, as the entire stand is balanced at bearing 18 in any case, so that practically no significant bending forces appear at the interface 98a. In one preferred embodiment a damping intermediate layer is placed at interface 96a.

However, the invention also covers placement of comparable interfaces at other points 96 b-k. They make it possible to connect the tubes forming the arms to other parts, and also, as much as possible, prevent conduction of vibrations through the system. Vibration-damping intermediate layers 99 can also be installed in regions with bending stress, such as 96 a-k. Their function is to destroy mechanical vibrations, or to convert them into frictional energy or heat. Figure 8, for example, shows one particular intermediate layer 99a damping the vibration at the interface 96k between the pivot bearing 34 of the food 23 and the pillar 1c. Both bending force vibrations and longitudinal vibrations are damped by the intermediate layer 99a.

In addition, or alternatively, supporting feet 100 can be provided as shown in Figure 1. They support the stand above the floor in its working position. The supporting feet 100

have vibration-damping intermediate layers 99b which support the base on the floor (Figure 5). Of course, such intermediate layers can also be placed between the supporting feet 100 and the base 23.

Figure 2 shows, as an alternative, that such intermediate layers 99c,d can also be placed between the base 23 and the wheels 25a,b.

The intermediate layers 99b-d act primarily to damp vertical vibrations. However, they also damp vibrations of the pillar 1 about a horizontal plane, as the base 23 diverts these vibrations, though its lever arm function, into approximately vertical vibrations at the intermediate layers (cushions). The intermediate layers 99b (Figures 5 and 6) also act as frictional dampers between the base 23 and the floor in case of certain vibrations of the entire system out of a vertical plane.

Figure 5 - 7 present a preferred base structure with rollers 25b for transportation and the feet 100 which can be lowered by a mechanism. For each foot 100, the mechanism comprises a coarsely threaded rod 106 connected to a gear 105 which can be driven by the adjusting chain 101. As all the gears 105 of all the feet 100 are driven by the same chain 101, the feet are raised or lowered together on changing between the transport position and the working position.

Figure 7 shows a length adjustment 102 with which the chain 101 can be tight~~ened~~, and an adjusting drive 103 with a drive shaft, by which the ~~chain 101~~ can be driven. The adjusting drive has an eccentric gear 109 ~~which~~ allows the feet 100 to be quickly adjusted ~~and also~~ fixed well in the ~~selected position.~~

The stand base 23 has a special structure according to the invention. Its housing 33 has, as shown in Figures 5 and 6, a lower plate 107 and an upper plate 108, which are

fastened together in the vicinity of the rollers 25. The connection is made through a pot-like projection of the lower plate 107 or through an inserted piece that is bolted to both the upper and lower plates. Due to that structure, tensile and compressive forces and bendings are mutually supported. A honeycomb structure 110 is cemented between the plates 107 and 108 for further stiffening of the base 23. Both the plates and the honeycomb structure are made of aluminum alloy for light construction.

There is a recess 111 at about the center of the base 23 (Figure 5). It holds the pivot bearing 34 for the pillar 1.

The supports 1, 2, 4, 16, 40 are preferably made of fiber-reinforced plastic, and are correspondingly light, so that the balancing weight 5 (Figure 1) can also be light, and the weight of the entire structure is lower than for the usual designs.

Figure 3 shows symbolically how the fibers 98 are oriented in the example embodiment. Four fiber layers 98a-98d have angles varying from ± 40-50° to 0° (direction of the tube 97 used as a support). Adjoining angled layers (40°, 50°) give an effective layer angle of 45° (98c) which is important to get flexural or torsional stiffness. However, such small angular differences increase the breaking strength somewhat over a single-layer angle (as of just 45°), as the adjacent fibers obviously block what would otherwise be a preferred direction of breaking along the layer of winding.

The fiber orientation of the fibers 98e in the composite tube 97a as shown in Figure 4 is in the null position. The tube 97a is combined with an aluminum tube 97b or with another tube having a distinctly different modulus of elasticity. If desired, the aluminum tube can also be on the outside of the tube. Composite tubes with sandwich construction are also covered by the invention. The connection between the two tubes may also be elastic to thrust, so that slight relative axial movements, preferably damped by friction, are possible.

The particular prestressed variants as shown in Figures 10 and 11 have the advantage of high strength with further reduced weight. The potential for prestressing is reasonably applicable to both vertical and horizontal supports.

Metallic interfaces 96L or 96m as shown in Figure 10 form the ends of a composite tube 97a. A stressing rod 112a passes axially through tube 97a. It is supported by screws, secured against rotation, or prestressed, at each interface 96l, 96m. The choice of prestress is done in assembly with, for instance, a torque driver.

The variant shown in Figure 11, however, has a tensioning cable 112b. It is fastened at both ends to an anchoring wire mount 114a or 114b. It is shown symbolically as looped around the mount. Obviously, it can also be held by a screw-nut structure as in Figure 10. A tightening mechanism, which is itself well known, for tightening the wires or cable, is not shown.

Appropriate prestressing of the rod 112a or the cable 112b gives a more than proportional increase in the flexural stiffness of the tube 97a or 97 without significantly increasing the weight of the microscope stand. Accordingly, the weight can also be reduced with the same flexural stiffness.

It is also possible to fill the hollow in the tube or composite tube with foam for greater vibration damping.

The different damping measures described above can be improved even more by combining them: fiber composite/metal tubes as supports, damped or vibration-isolated interfaces in the stand and damped supports on the floor. The lower the masses are, the lower the inertial vibrating masses.

List of reference symbols

1 a-d	Stand
2 a,b,d	Load arm, optionally constructed of several rods, such as one or more parallelogram guides
3	Load, such as a surgical microscope; but it could be any part which must be mounted on a stand, such as a robot arm, video camera, telescope, or the like
4 a	Balance arm, optionally constructed of several rods, such as one or more parallelogram guides
5 a,b	Movable balance weight
8	Load mount; includes means to hold a microscope or other load; especially a swivel mount
9	Pivot axis (horizontal pivoting axis) for the load arm 2 and/or balancing arm 4, on which they can pivot out of the horizontal plane 63
16 a,b	Tension arm horizontal (a), vertical (b)
18	Pivoting axis (vertical pivoting axis) about which the stand can pivot out of the vertical plane 64
23	Base of the stand

25 a,b	Wheels for the base. They can be mounted rigidly (only one preferred direction of movement) or so that they can turn. They are preferably lockable, or withdrawable into the base 23 to allow setting the base 23 down on the floor if no separate feet are provided
33	Housing
34	Pivot bearing
40 a,b	Pivoting stand; in the rest position a vertical part which carries the horizontal pivot bearing 9
63	Horizontal plane
96 a-m	Interfaces; connection between two adjacent parts of the stand, optionally with elastic, vibration-damping intermediate layer 99, as of an elastomer, polyurethane or rubber, or the like with high damping
97	Fiber-reinforced tube for stand support
97a	Composite tube of metal/fiber-reinforced plastic
98 a-e	Fiber layers of carbon or the like
99 a-d	Vibration-damping intermediate layers
100 a-d	Supporting foot; positioning foot

101	Adjusting chain
102	Length adjustment
103	Positioning drive
104	Driveshaft
105	Gear wheel
106	Coarse thread
107	Lower plate
108	Upper plate
109	Eccentric mechanism
110	Honeycomb structure
111	Recess
112	a) Tension rod with threaded ends or b) Tension wire
113	Tightening nuts
114a, b	Anchoring wire mount, specifically crossed